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Motegi

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(54) **IMAGE FORMING APPARATUS**

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G03G 15/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/065*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/065
See application file for complete search history.

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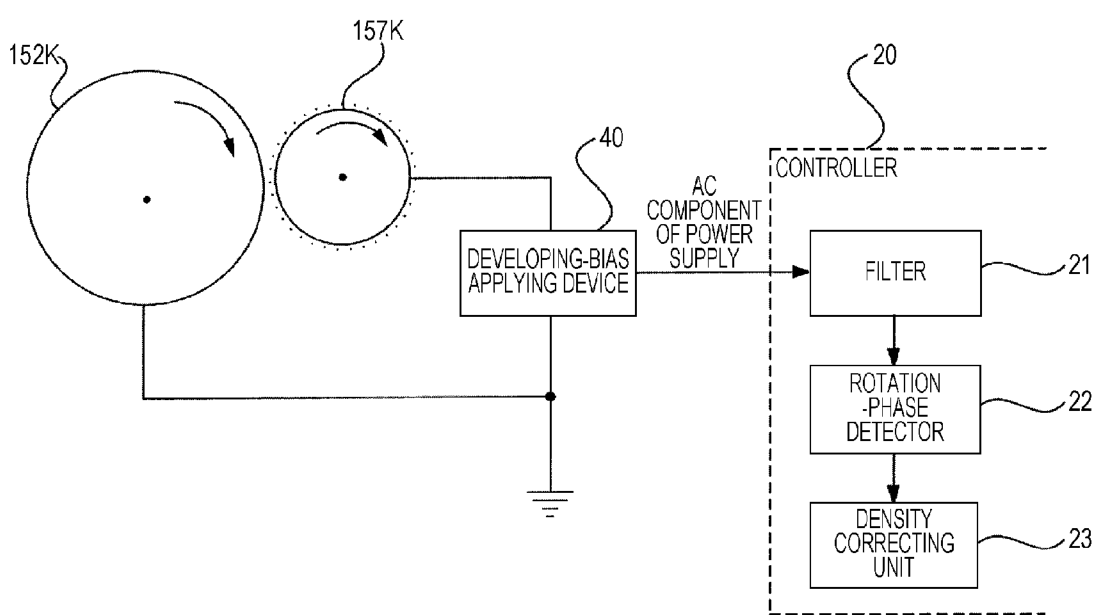
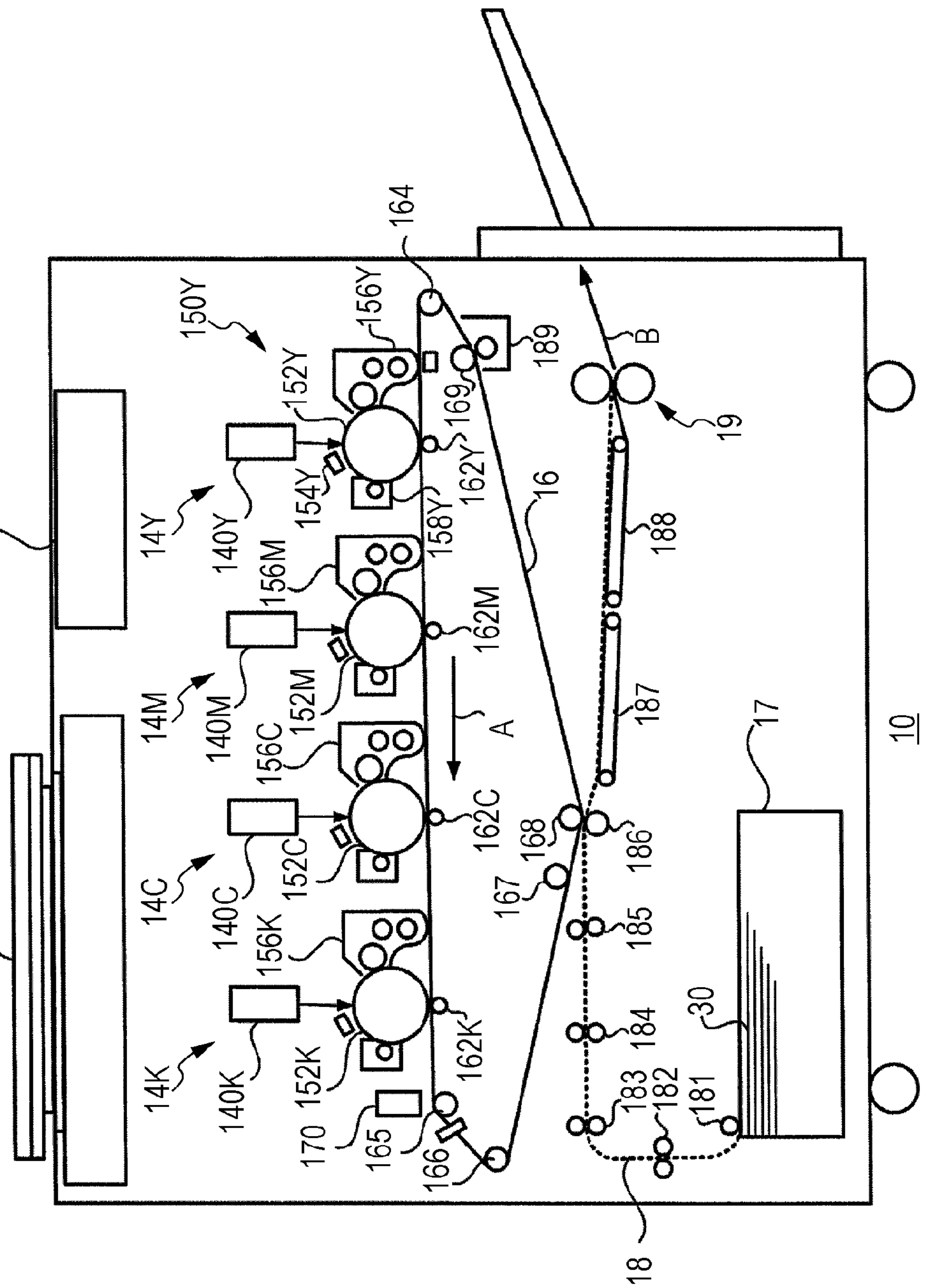
(57) **ABSTRACT**

An image forming apparatus includes an image carrier that holds a developer image, a developer transport unit that transports a developer to the image carrier by performing a rotational movement, a voltage application unit that applies, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier, and a detector that detects a rotation phase of the developer transport unit from an alternating-current component waveform of a power supply of the voltage application unit.

14 Claims, 9 Drawing Sheets




12
20
10
14K
14C
14M
14Y
140K
140C
140M
140Y
150Y
152K
152C
152M
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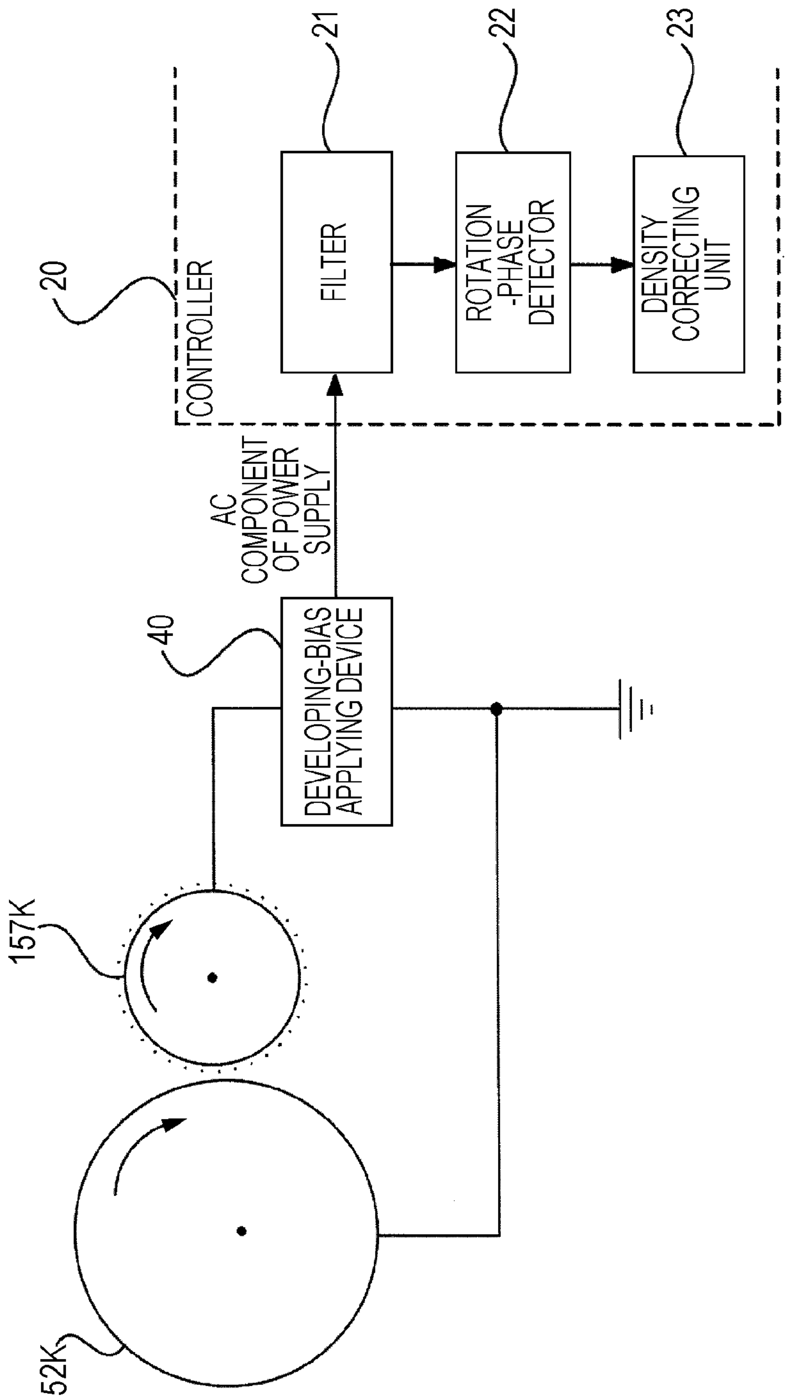
154Y
156K
156C
156M
156Y
158Y
162K
162C
162M
162Y
164
165
166
167
168
169
170
16
17
18
19
30
181
182
183
184
185
186
187
188
189
A
B

FIG. 1

FIG. 2


20
CONTROLLER
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FILTER
22
ROTATION
-PHASE
DETECTOR
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DENSITY
CORRECTING
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AC
COMPONENT
OF POWER
SUPPLY
40
DEVELOPING-BIAS
APPLYING DEVICE
157K
152K

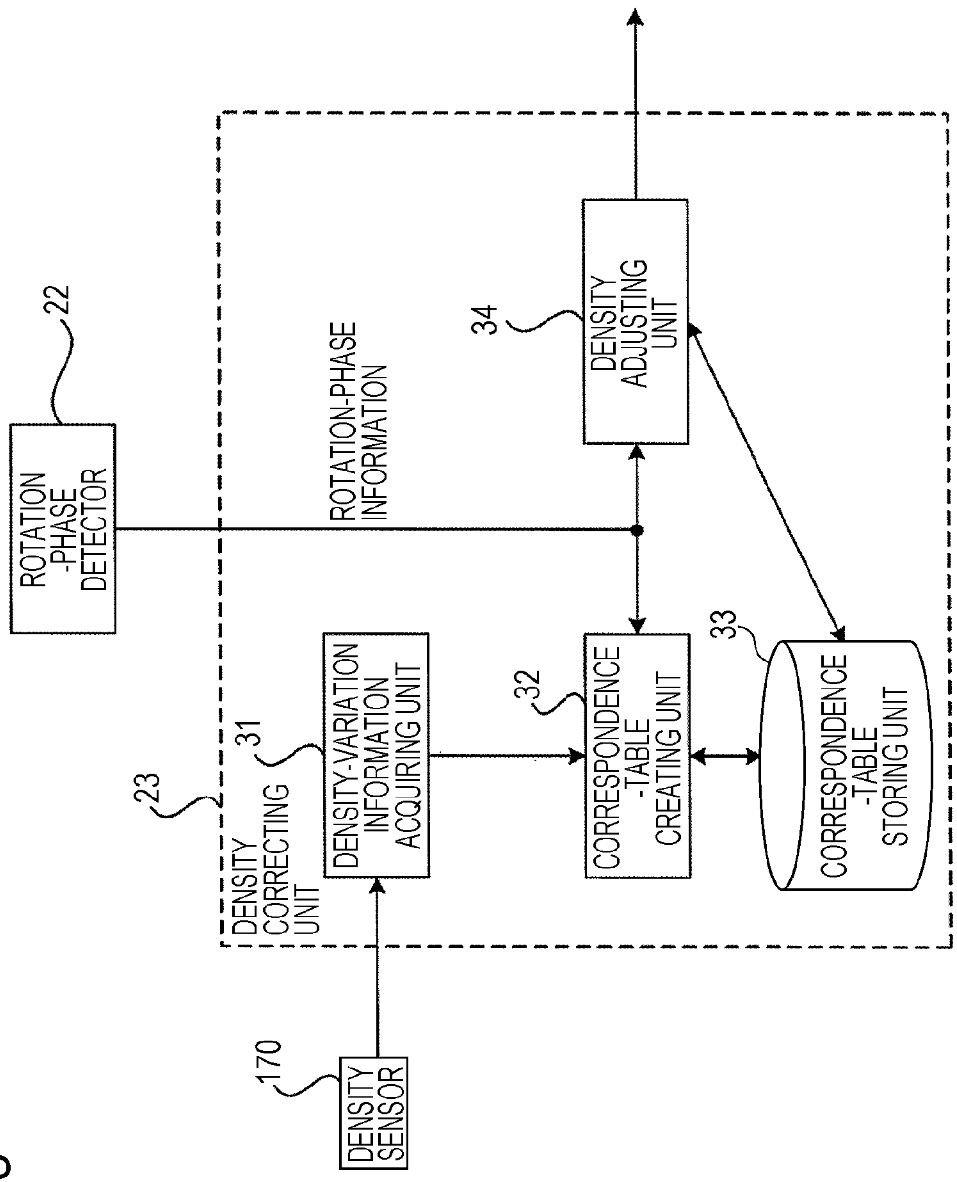

22
ROTATION-PHASE DETECTOR
ROTATION-PHASE INFORMATION
23
DENSITY CORRECTING UNIT
31
DENSITY-VARIATION INFORMATION ACQUIRING UNIT
32
CORRESPONDENCE-TABLE CREATING UNIT
33
CORRESPONDENCE-TABLE STORING UNIT
34
DENSITY ADJUSTING UNIT
170
DENSITY SENSOR

FIG. 3

FIG. 4A

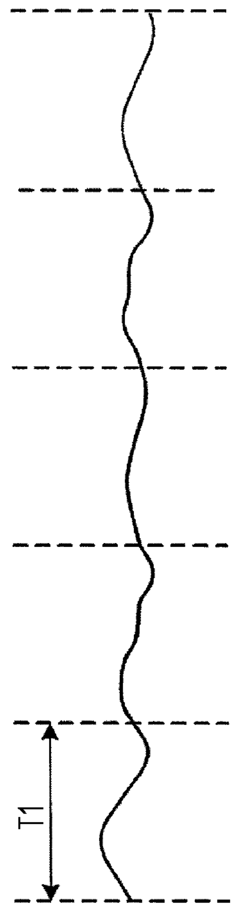


FIG. 4B

FIG. 5

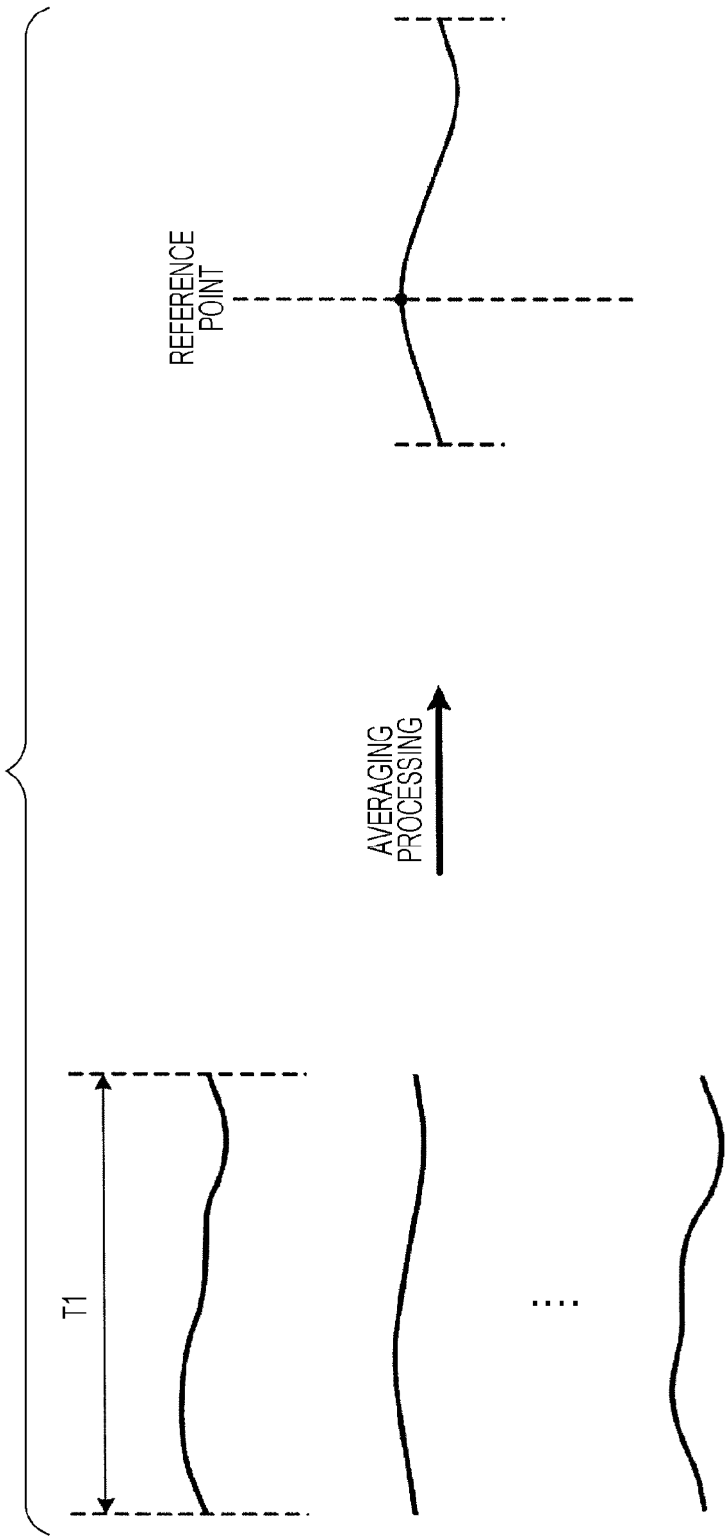
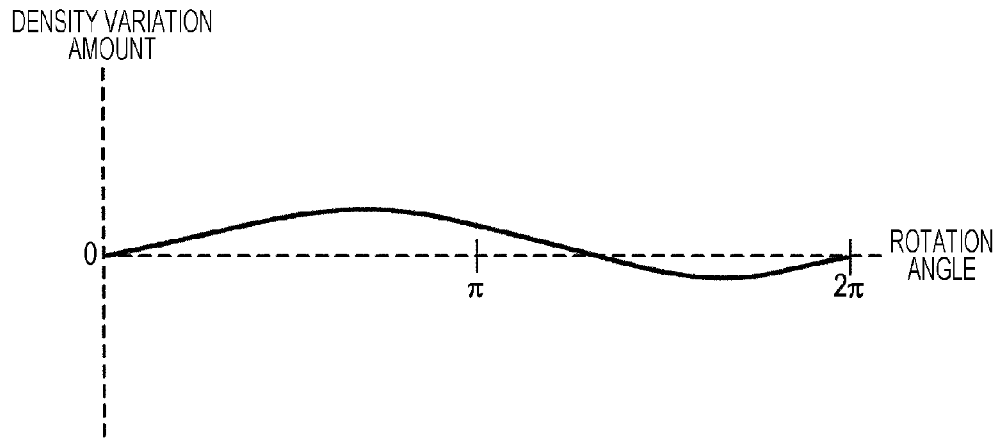


FIG. 6A


DENSITY VARIATION AMOUNT
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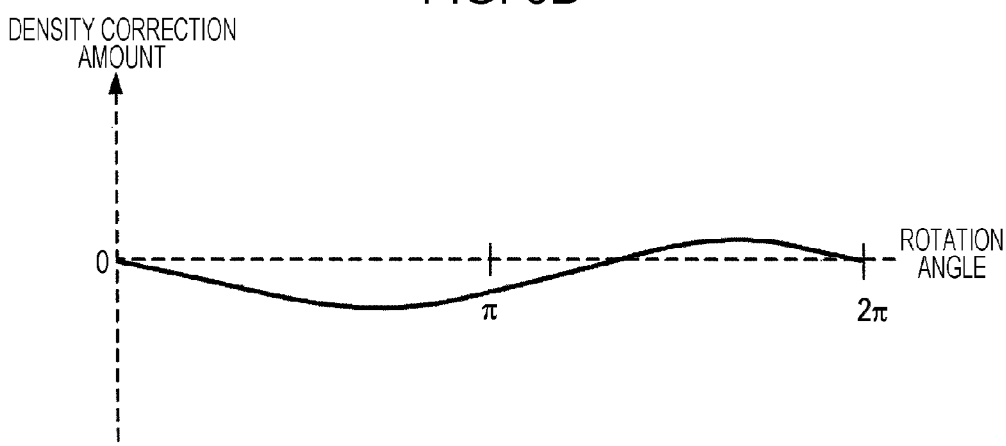
π
2π
ROTATION ANGLE

FIG. 6B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π
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ROTATION ANGLE

FIG. 7A

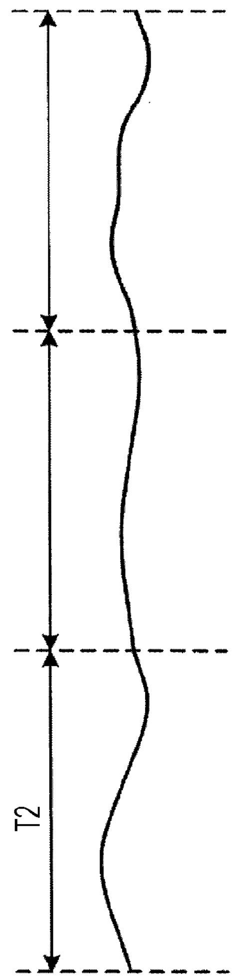


FIG. 7B

FIG. 8

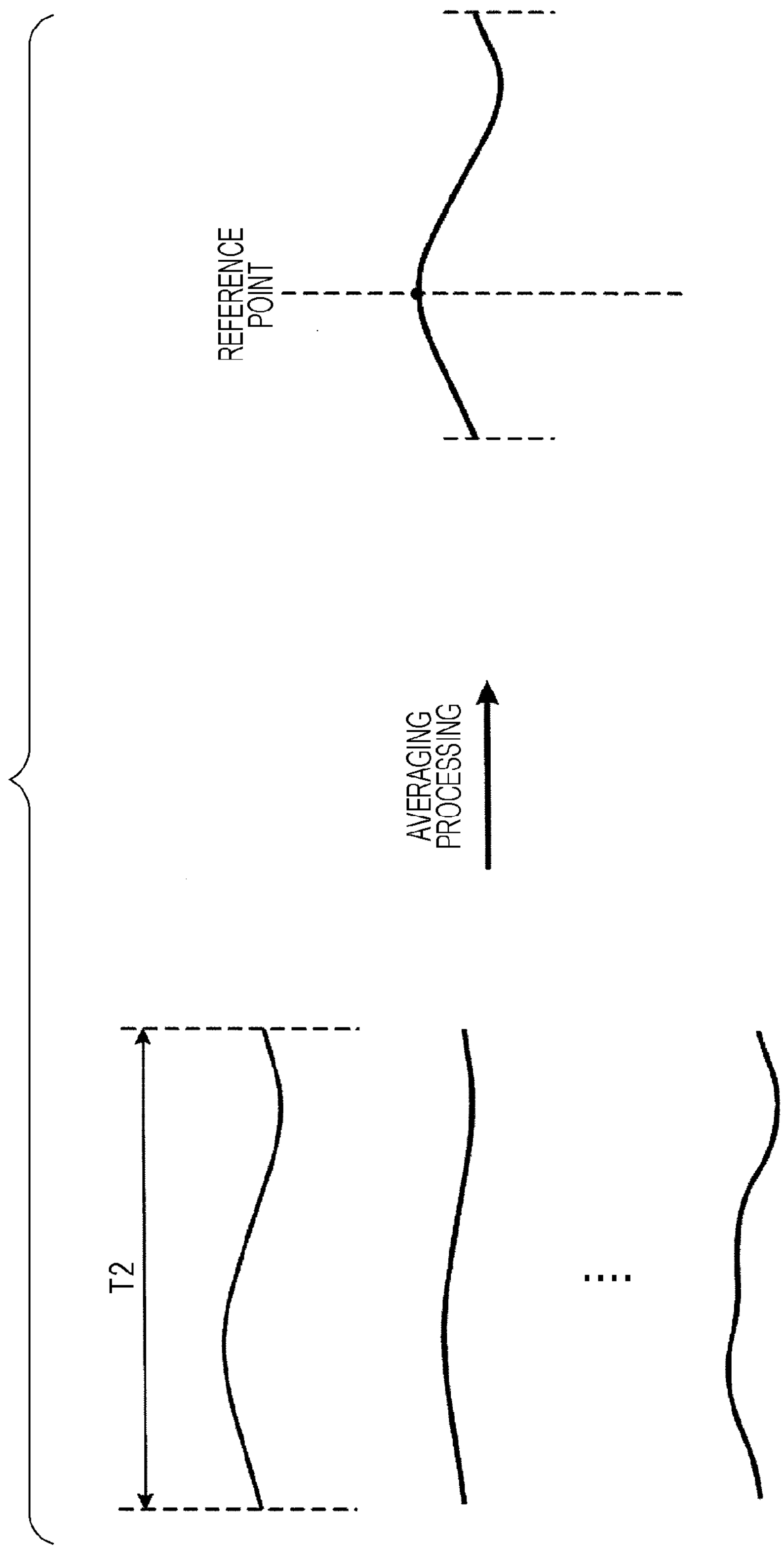
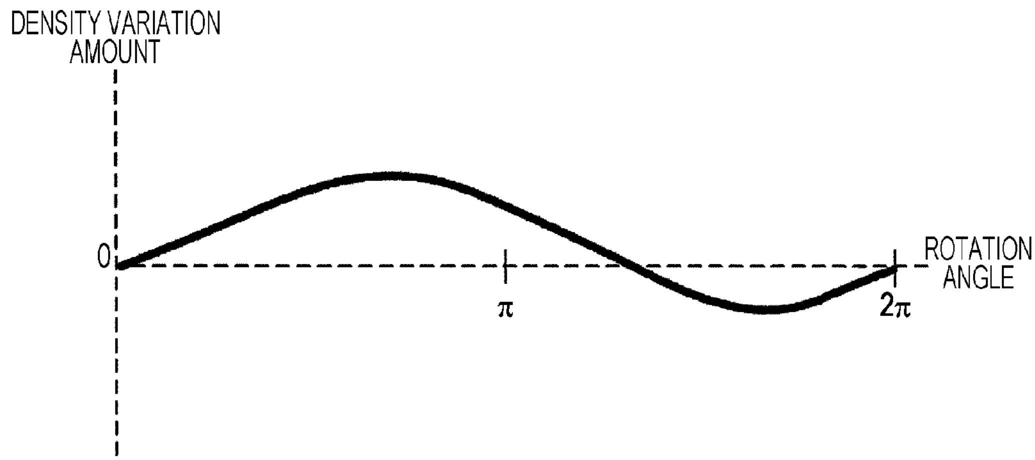


FIG. 9A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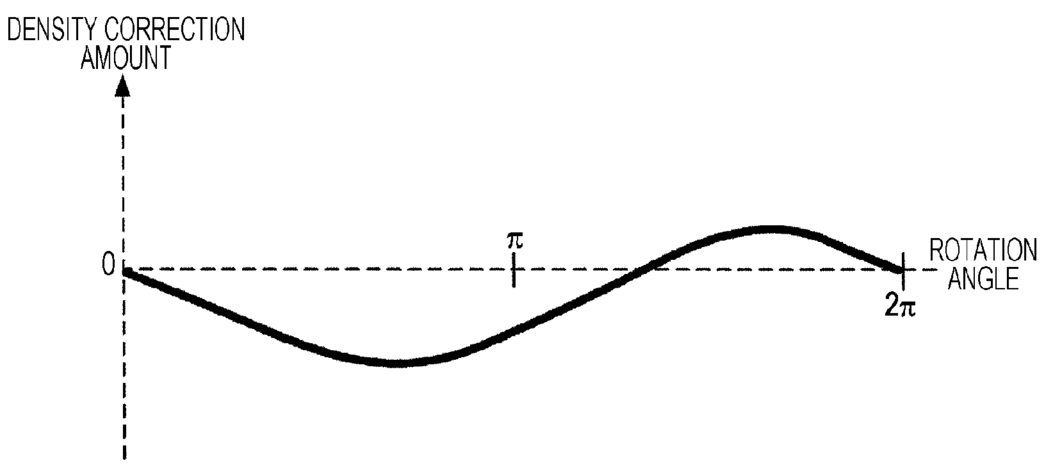
π
2π
ROTATION ANGLE

FIG. 9B


DENSITY CORRECTION AMOUNT
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π
2π
ROTATION ANGLE

IMAGE FORMING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2015-057812 filed Mar. 20, 2015.

BACKGROUND

Technical Field

The present invention relates to an image forming apparatus.

SUMMARY

According to an aspect of the invention, there is provided an image forming apparatus including an image carrier that holds a developer image, a developer transport unit that transports a developer to the image carrier by performing a rotational movement, a voltage application unit that applies, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier, and a detector that detects a rotation phase of the developer transport unit from an alternating-current component waveform of a power supply of the voltage application unit.

BRIEF DESCRIPTION OF THE DRAWINGS

An exemplary embodiment of the present invention will be described in detail based on the following figures, wherein:

FIG. **1** is a diagram illustrating a configuration of an image forming apparatus according to an exemplary embodiment of the present invention;

FIG. **2** is a diagram illustrating a relationship between a photoconductor drum and a developing roller in the image forming apparatus according to the exemplary embodiment of the present invention;

FIG. **3** is a block diagram illustrating a detailed configuration of a density correcting unit illustrated in FIG. **2**;

FIG. **4**A and FIG. **4**B, respectively are a diagram illustrating an exemplary waveform of an AC component of a power supply that is output by a developing-bias applying device and a diagram illustrating an exemplary waveform obtained after the waveform of the AC component of the power supply has passed through a filter;

FIG. **5** is a diagram illustrating averaging processing performed by a rotation-phase detector;

FIG. **6**A and FIG. **6**B, respectively are a diagram illustrating an example of a density variation (density unevenness) profile for the developing roller and a diagram illustrating an example of a density correction profile;

FIG. **7**A and FIG. **7**B, respectively are a diagram illustrating an exemplary waveform of the AC component of the power supply that is output by the developing-bias applying device and a diagram illustrating an exemplary waveform obtained after the waveform of the AC component of the power supply has passed through the filter;

FIG. **8** is a diagram illustrating the averaging processing performed by the rotation-phase detector; and

FIG. **9**A and FIG. **9**B, respectively are a diagram illustrating an example of a density variation (density unevenness) profile for the photoconductor drum and a diagram illustrating an example of a density correction profile.

DETAILED DESCRIPTION

An exemplary embodiment of the present invention will now be described in detail with reference to the drawings.

FIG. **1** is a diagram illustrating the configuration of an image forming apparatus **10** according to the exemplary embodiment of the present invention.

As illustrated in FIG. **1**, the image forming apparatus **10** includes an image reading device **12**, image forming units **14**K, **14**C, **14**M, and **14**Y, an intermediate transfer belt **16**, a sheet tray **17**, a sheet transport path **18**, a fixing unit **19**, and a controller **20**. The image forming apparatus **10** may be a multifunction machine that has a printer function that prints image data, which is received from a personal computer (not illustrated) or the like, and also has a function of serving as a full-color copying machine using the image reading device **12** and a function of serving as a facsimile machine.

An overview of the image forming apparatus **10** will be described first. The image reading device **12** and the controller **20** are disposed in an upper portion of the image forming apparatus **10** and each function as a unit for inputting image data. The image reading device **12** reads an image of a document and outputs the image to the controller **20**. The controller **20** performs image processing, such as gradation correction and resolution correction, on image data that is input therein by the image reading device **12** or image data that is input therein by a personal computer (not illustrated) or the like via a network line, such as a LAN, and then outputs the image data to the image forming units **14**.

The four image forming units **14**K, **14**C, **14**M, and **14**Y, each of which corresponds to one of the colors of color images, are disposed below the image reading device **12**. In the present exemplary embodiment, the four image forming units **14**K, **14**C, **14**M, and **14**Y that correspond to black (K), cyan (C), magenta (M), and yellow (Y), respectively, are horizontally arranged with a predetermined interval therebetween along the intermediate transfer belt **16**. The intermediate transfer belt **16** serves as an intermediate transfer body and rotates in the direction of arrow A in FIG. **1**, and the four image forming units **14**K, **14**Y, **14**M, and **14**C sequentially form toner images of the corresponding colors on the basis of image data input by the controller **20** and transfer (in a first transfer process) the plural toner images onto the intermediate transfer belt **16** at the timing at which the plural toner images are superposed with one another. Note that the image forming units **14**K, **14**C, **14**M, and **14**Y are not limited to being arranged in the order of colors K, C, M, and Y and may be in any order (e.g., Y, M, C, and K).

The sheet transport path **18** is disposed below the intermediate transfer belt **16**. One of the recording sheets **30** that is supplied from the sheet tray **17** is transported along the sheet transport path **18**, and toner images, which have been transferred to the intermediate transfer belt **16** in such a manner that the toner images are superposed with one another, are collectively transferred (in a second transfer process) on to the recording sheet **30**. Then, the toner images, which have been transferred to the recording sheet **30**, is fixed onto the recording sheet **30** by the fixing unit **19**, and the recording sheet **30** is ejected to the outside in the direction of arrow B.

The configuration of each unit included in the image forming apparatus **10** will now be described in further detail.

The controller **20** performs predetermined image processing, such as shading correction, document misregistration correction, brightness/color space conversion, gamma correction, frame erase, and color/movement editing, on image data read by the image reading device **12**. Note that optical images reflected from a color material of the document, which is read by the image reading device **12**, are document-reflectance data items, each of which has one of three colors of, for example, red (R), green (G), and blue (B) and each of which is composed of 8 bits, and these document reflectance data items are converted into document-color-material-gradation data items, each of which has one of four colors of K, C, M, and Y and each of which is composed of 8 bits through the image processing performed by the controller **20**.

The image forming units **14**K, **14**C, **14**M, and **14**Y (image forming units) are arranged side by side with a predetermined interval therebetween in the horizontal direction, and the configurations of the image forming units **14**K, **14**C, **14**M, and **14**Y are substantially similar to one another except for the colors of images formed by the image forming units **14**K, **14**C, **14**M, and **14**Y. Accordingly, the image forming unit **14**K will be described below. Note that the configurations of the image forming units **14** will be described in such a manner as to be distinguished in terms of color by adding the letters K, C, M, and Y to the reference numeral **14**.

The image forming unit **14**K includes a light scanning device **140**K that causes a laser beam to scan a photoconductor drum **152**K in accordance with image data, which is input from the controller **20**, and an image forming device **150**K that forms an electrostatic latent image by using the laser beam, which is caused to scan the photoconductor drum **152**K by the light scanning device **140**K.

The light scanning device **140**K modulates the laser beam in accordance with a black (K) image data and radiates the modulated laser beam onto the photoconductor drum **152**K of the image forming device **150**K.

The image forming device **150**K includes the photoconductor drum **152**K that performs a rotational movement in the direction of arrow A at a predetermined rotation speed, a charging device **154**K serving as a charging unit that uniformly charges a surface of the photoconductor drum **152**K, a developing device **156**K that develops an electrostatic latent image formed on the photoconductor drum **152**K, and a cleaning device **158**K. The photoconductor drum **152**K is an image carrier, which has a cylindrical shape or a substantially cylindrical shape and holds a developer image, such as a toner image, and is uniformly charged by the charging device **154**K. An electrostatic latent image is formed on the photoconductor drum **152**K by the laser beam that is radiated from the light scanning device **140**K. The electrostatic latent image formed on the photoconductor drum **152**K is developed by the developing device **156**K with a developer, such as a black (K) toner, and transferred onto the intermediate transfer belt **16**. Note that residual toner, paper dust, and the like that remain on the photoconductor drum **152**K after a process of transferring a toner image (developer image) is removed by the cleaning device **158**K.

Similar to the image forming unit **14**K, the image forming unit **14**C includes a photoconductor drum **152**C and a developing device **156**C and forms a toner image of cyan (C). The image forming unit **14**M includes a photoconductor drum **152**M and a developing device **156**M and forms a toner image of magenta (M). The image forming unit **14**Y includes a photoconductor drum **152**Y and a developing device **156**Y and forms a toner image of yellow (Y). These toner images of the different colors, which are formed, are transferred onto the intermediate transfer belt **16**.

The intermediate transfer belt **16** is stretched by a drive roller **164**, idle rollers **165**, **166**, and **167**, a backup roller **168**, and an idle roller **169** with a certain tension and is driven so as to rotate at a predetermined speed in the direction of arrow A as a result of the drive roller **164** being driven by a drive motor (not illustrated) so as to rotate. The intermediate transfer belt **16** has the form of an endless belt obtained by, for example, forming a flexible film made of a synthetic resin, such as a polyimide, into a belt-like shape and joining the ends of the synthetic resin film, which is formed in a belt-like shape, to each other by welding or the like.

First transfer rollers **162**K, **162**C, **162**M, and **162**Y are disposed on the intermediate transfer belt **16** at positions facing the image forming units **14**K, **14**C, **14**M, and **14**Y, respectively, and toner images of the different colors formed on the photoconductor drums **152**K, **152**C, **152**M, and **152**Y are transferred onto the intermediate transfer belt **16** by the first transfer rollers **162** in such a manner that the toner images are superposed with one another. Note that residual toner that remains on the intermediate transfer belt **16** is removed by a cleaning blade or a brush of a belt cleaning device **189** that is disposed on a downstream side of a second transfer position.

A density sensor **170** is disposed in the vicinity of the intermediate transfer belt **16**. The density sensor **170** is a sensor that is used for reading toner images transferred to the intermediate transfer belt **16**.

A sheet feed roller **181** that picks up one of the recording sheets **30** from the sheet tray **17**, first pair of rollers **182**, second pair of rollers **183**, third pair of rollers **184** that are used for transporting the recording sheet **30**, and registration rollers **185** that transport the recording sheet **30** to the second transfer position at a predetermined timing are disposed on the sheet transport path **18**.

A second transfer roller **186** that is pressed into contact with the backup roller **168** is disposed at the second transfer position on the sheet transport path **18**, and toner images of the different colors, which have been transferred to the intermediate transfer belt **16** in such a manner that the toner images are superposed with one another, are transferred in the second transfer process onto the recording sheet **30** with a press-contact force and an electrostatic force exerted by the second transfer roller **186**. The recording sheet **30**, to which the toner images of the different colors have been transferred, is transported to the fixing unit **19** by a transport belt **187** and a transport belt **188**.

The fixing unit **19** performs a heat treatment and a pressure treatment on the recording sheet **30**, to which the toner images of the different colors have been transferred, so as to cause the toners to melt and become fixed onto the recording sheet **30**.

The developing device **156**K includes a developing roller (developer transport unit) **157**K that has a cylindrical shape and transports the developer to the photoconductor drum **152**K by performing a rotational movement so as to form a developer image on the photoconductor drum **152**K. Regarding the image forming units **14**C, **14**M, and **14**Y, that form images of the other colors, similar to the image forming unit **14**K, a developing roller is provided in each of the developing devices **156**C, **156**M, and **156**Y.

A relationship between the photoconductor drum **152**Y and the developing roller **157**K in the image forming apparatus **10** according to the present exemplary embodiment will now be described with reference to FIG. **2**. Note that, FIG. **2** only illustrates the configuration for forming a black image, and the configurations for forming images of the other colors of cyan, magenta, and yellow are similar to the configuration for forming a black image.

As illustrated in FIG. **2**, the photoconductor drum **152**K and the developing roller **157**K are arranged in such a manner as to face each other with a predetermined interval (gap) therebetween. The developing roller **157**K holds the developer on its surface by a magnetic force of a magnet, which is disposed in the developing roller **157**K, and transports the developer to a gap defined between the developing roller **157**K and the photoconductor drum **152**K by performing a rotational movement so as to develop a latent image, which is formed on the surface of the photoconductor drum **152**K, into a visible image.

As illustrated in FIG. **2**, the image forming apparatus **10** according to the present exemplary embodiment includes a developing-bias applying device **40**.

The developing-bias applying device **40** is a voltage application unit that applies, between the developing roller **157**K and the photoconductor drum **152**K, a voltage (developing bias), which is formed of a direct-current voltage component (DC voltage component) and an alternating-current voltage component (AC voltage component) and used for transporting the developer from the developing roller **157**K to the photoconductor drum **152**K.

Here, since both the photoconductor drum **152**K and the developing roller **157**K are made of a metal material, the photoconductor drum **152**K and the developing roller **157**K function in a similar way to a capacitor.

In the case where the photoconductor drum **152**K, the developing roller **157**K, and the like each have an ideal configuration, an AC component of a power supply of the developing-bias applying device **40** would have been zero on average. However, in the case where the gap between the photoconductor drum **152**K and the developing roller **157**K changes upon rotational movements of the photoconductor drum **152**K and the developing roller **157**K due to manufacturing tolerances and the like of the photoconductor drum **152**K and the developing roller **157**K, the capacitance of the capacitor formed of the photoconductor drum **152**K and the developing roller **157**K, also changes, and as a result, the value of the current of the AC component of the power supply included in the developing-bias applying device **40** changes.

The developing-bias applying device **40** according to the present exemplary embodiment includes a stabilizing circuit that performs feedback control so as to stabilize an output voltage.

The controller **20** detects rotation phases of the photoconductor drum **152**K and the developing roller **157**K by using the AC component waveform of the power supply of the developing-bias applying device **40** and corrects density variations (unevenness in density) due to rotation of the photoconductor drum **152**K or the developing roller **157**K.

A specific configuration in which the controller **20** detects the rotation phase of the photoconductor drum **152**K or the developing roller **157**K on the basis of an AC component waveform of the power supply of the developing-bias applying device **40** and corrects density variations will now be described.

As illustrated in FIG. **2**, the controller **20** includes a filter **21**, a rotation-phase detector **22**, and a density correcting unit **23**.

The filter **21** is a filter, such as a low-pass filter (LPF), that is used for removing high-frequency component noise from an AC component waveform of the power supply of the developing-bias applying device **40**. The filter **21** may be realized by using, for example, a digital filter.

Note that providing the filter **21** may result in a delay. However, if the duration of a delay that occurs when a rotation phase is detected and the duration of a delay that occurs when density variations are actually corrected are the same as each other, such a delay will not be a problem when the density variations are corrected.

The rotation-phase detector **22** detects the rotation phase of the developing roller **157**K on the basis of an AC component waveform of the power supply of the developing-bias applying device **40** that has passed through the filter **21**.

More specifically, the rotation-phase detector **22** divides the AC component waveform of the power supply of the developing-bias applying device **40** into regions corresponding to each rotation period of the developing roller **157**K and calculates the average value of the divided plural regions of the AC component waveform. Then, the rotation-phase detector **22** detects a feature point of the average value of the AC component waveform, which has been calculated, so as to set a reference point of the rotation phase of the developing roller **157**K.

The density correcting unit **23** corrects density variations due to rotation of the developing roller **157**K on the basis of the rotation phase of the developing roller **157**K, which has been detected by the rotation-phase detector **22**. More specifically, the density correcting unit **23** performs density corrections that cancel out the density variations due to the rotation of the developing roller **157**K by synchronizing the rotation of the developing roller **157**K and the density corrections with each other in accordance with a reference point set by the rotation-phase detector **22**.

Note that the density correcting unit **23** may be configured not to correct the density variations by considering the density variations, which occur as a result of rotation of the developing roller **157**K or the like, to be allowable values or smaller in the case where the variation amount of the AC component waveform of the power supply of the developing-bias applying device **40** is smaller than a predetermined value, that is, for example, in the case where the difference between the maximum value and the minimum value is a predetermined value or smaller.

The rotation-phase detector **22** may detect the rotation phase of the photoconductor drum **152**K on the basis of the AC component waveform of the power supply of the developing-bias applying device **40**.

In this case, the rotation-phase detector **22** divides the AC component waveform of the power supply of the developing-bias applying device **40** into regions corresponding to each rotation period of the photoconductor drum **152**K and calculates the average value of the divided plural regions of the AC component waveform. Then, the rotation-phase detector **22** detects a feature point of the average value of the AC component waveform, which has been calculated, so as to set a reference point of the rotation phase of the photoconductor drum **152**K.

Then, the density correcting unit **23** corrects density variations due to rotation of the photoconductor drum **152**K on the basis of the rotation phase of the photoconductor drum **152**K detected by the rotation-phase detector **22**.

The detailed configuration of the density correcting unit **23** will now be described with reference to FIG. **3**, which is a block diagram.

As illustrated in FIG. **3**, the density correcting unit **23** includes a density-variation information acquiring unit **31**, a correspondence-table creating unit **32**, a correspondence-table storing unit **33**, and a density adjusting unit **34**.

Although the case of correcting density variations that occur due to rotation of the developing roller **157**K will be described below, a similar method may be used in the case of correcting density variations that occur due to rotation of the photoconductor drum **152**K.

The density-variation information acquiring unit **31** acquires density-variation information that corresponds to the rotation phase of the developing roller **157**K by detecting the density of an image that is formed on the photoconductor drum **152**K with the developer, which has been transported by the developing roller **157**K. More specifically, the density-variation information acquiring unit **31** detects the density value of a black toner image on the intermediate transfer belt **16**, which has been detected by the density sensor **170**.

Then, the correspondence-table creating unit **32** creates, on the basis of the density-variation information acquired by the density-variation information acquiring unit **31** and the information regarding the rotation phase of the developing roller **157**K detected by the rotation-phase detector **22**, a correspondence table in which a correction amount corresponding to the rotation phase of the developing roller **157**K is specified.

The correspondence table, which is created by the correspondence-table creating unit **32** and in which the rotation phase of the developing roller **157**K and a density correction amount are specified, is stored in the correspondence-table storing unit **33**.

The density adjusting unit **34** adjusts the density value of each pixel of an image to be formed on the basis of the rotation phase of the developing roller **157**K, which is detected by the rotation-phase detector **22**, and the correspondence table, which is created by the correspondence-table creating unit **32** and stored in the correspondence-table storing unit **33**.

A specific method of creating a density correction profile for detecting the rotation phase of the developing roller **157**K and correcting density variations that occur due to rotation of the developing roller **157**K will now be described with reference to FIG. **4**A to FIG. **6**B.

FIG. **4**A illustrates an exemplary waveform of the AC component of the power supply that is output by the developing-bias applying device **40**. FIG. **4**B illustrates an exemplary waveform obtained after the waveform of the AC component of the power supply has passed through the filter **21**.

In the case where the rotation-phase detector **22** detects the rotation phase of the developing roller **157**K, the rotation-phase detector **22** divides the AC component waveform illustrated in FIG. **4**B into regions corresponding to each rotation period T**1** of the developing roller **157**K.

Then, as illustrated in FIG. **5**, the rotation-phase detector **22** performs averaging processing on the divided plural regions of the AC component waveform so as to calculate the average value and detects a feature point of the average value of the AC component waveform, which has been calculated.

More specifically, the rotation-phase detector **22** detects feature points, which are the maximum value, the minimum value, and the like of the AC component waveform that has undergone the averaging processing, and sets a reference point of the rotation phase of the developing roller **157**K by using each of the feature points as a reference position.

In the example illustrated in FIG. **5**, the rotation-phase detector **22** sets the minimum value of the AC component waveform, which has undergone the averaging processing, as the reference point of the rotation phase of the developing roller **157**K.

Subsequently, the density correcting unit **23** creates a density variation (density unevenness) profile for the developing roller **157**K, which is illustrated in FIG. **6**A as an example, by using the rotation phase of the developing roller **157**K detected by the rotation-phase detector **22**.

In the density variation profile illustrated in FIG. **6**A, density variation amounts with respect to rotation angles 0 to 2π of the developing roller **157**K are shown as profiles.

The density correcting unit **23** calculates a density correction amount, which cancels out density variations such as those illustrated in FIG. **6**A, and creates a density correction profile such as that illustrated in FIG. **6**B.

In the density correction profile illustrated in FIG. **6**B, density correction amounts with respect to rotation angles 0 to 2π of the developing roller **157**K are shown as profiles.

In other words, the density correcting unit **23** performs density corrections on the basis of a density correction profile such as that illustrated in FIG. **6**B and the rotation phase of the developing roller **157**K, so that density variations due to rotation of the developing roller **157**K may be reduced.

A specific method of creating a density correction profile for detecting the rotation phase of the photoconductor drum **152**K and correcting density variations due to rotation of the photoconductor drum **152**K will now be described with reference to FIG. **7**A to FIG. **9**B.

FIG. **7**A illustrates an exemplary waveform of the AC component of the power supply that is output by the developing-bias applying device **40**. FIG. **7**B illustrates an exemplary waveform obtained after the waveform of the AC component of the power supply has passed through the filter **21**. Note that parameters that are different from those in the case of detecting the rotation phase of the developing roller **157**K are set to the filter **21** in order to obtain a varying waveform for detecting the rotation phase of the photoconductor drum **152**K.

In the case where the rotation-phase detector **22** detects the rotation phase of the photoconductor drum **152**K, as illustrated in FIG. **7**B, the rotation-phase detector **22** divides the AC component waveform into regions corresponding to each rotation period T**2** of the photoconductor drum **152**K.

Then, as illustrated in FIG. **8**, the rotation-phase detector **22** performs averaging processing on the divided plural regions of the AC component waveform by a method similar to that in the case of detecting the rotation phase of the developing roller **157**K so as to calculate the average value and detects a feature point of the average value of the AC component waveform, which has been calculated.

Subsequently, the density correcting unit **23** creates a density variation (density unevenness) profile for the photoconductor drum **152**K, such as that illustrated in FIG. **9**A as an example, by using the rotation phase of the photoconductor drum **152**K detected by the rotation-phase detector **22**. In addition, the density correcting unit **23** calculates a density correction amount, which cancels out density variations such as those illustrated in FIG. **9**A, and creates a density correction profile such as that illustrated in FIG. **9**B.

Then, the density correcting unit **23** performs density corrections on the basis of a density correction profile such as that illustrated in FIG. **9**B and the rotation phase of the photoconductor drum **152**K, so that density variations due to rotation of the photoconductor drum **152**K may be reduced as in the case of the developing roller **157**K.

Although the case of detecting a rotation phase of a rotating body, such as the developing roller **157**K or the photoconductor drum **152**K, in the image forming unit **14**K, which forms an image with a black toner, and correcting density variations due to rotation of the rotating body, such as the developing roller **157**K or the photoconductor drum **152**K, has been described above, density variations due to rotation of a rotating body are corrected in a similar manner also in each of the image forming units **14**C, **14**M and **14**Y. In other words, the rotation phases of the photoconductor drums **152**C, **152**M, and **152**Y and the rotation phases of the developing rollers are detected, and density variations are corrected also in the image forming units **14**C, **14**M and **14**Y.

In addition, in the case where the rotation phase of the developing roller **157**K or the photoconductor drum **152**K is detected in the above-described manner, the rotation phase may be kept updated to the most recent average value of the

AC component of the power supply of the developing-bias applying device **40** in a predetermined number of regions. Alternatively, after the rotation phase has been detected, the rotation phase may not be updated until one print job (print instruction) is completed. In other words, since the most recent rotation phase of the developing roller **157**K or the photoconductor drum **152**K may be estimated from the rotation phase, which has been detected, and the rotation period of the developing roller **157**K or the photoconductor drum **152**K, which is determined beforehand, correction of density variations may be performed periodically on the basis of the estimated rotation phase.

This is because a rotation phase relationship between rotating bodies, such as the developing roller **157**K and the photoconductor drum **152**K, will not be markedly changed until a series of image forming processing is completed. In addition, in the case where the most recent rotation phase is constantly being detected, and density variations are corrected on the basis of the detected rotation phase, when noise or the like is superposed on the waveform of the AC component of the power supply due to some unexpected factors, there is a possibility that the detected rotation phase will be displaced, and as a result, the density variations will not be appropriately corrected.

However, in the case where the print volume of one print job is excessive, if a rotation phase is not updated until this print job is completed, there is a possibility that the rotation phase will be gradually displaced, and as a result, the density variations will not be appropriately corrected. Therefore, it is desirable to detect the rotation phase of the rotating body again after a certain time has passed and update the rotation phase used as a basis for corrections of density variations.

[Modification]

Although the case of detecting a rotation phase of the rotating body (developing roller **157**K or photoconductor drum **152**K), whose rotation phase is to be detected, by dividing the AC component waveform of the power supply of the developing-bias applying device **40** in accordance with the rotation period of the rotating body, has been described in the above exemplary embodiment, the present invention is not limited to this. For example, a reference point used for detecting the rotation phase may be calculated by detecting a frequency component corresponding to the rotation period of the rotating body, whose rotation phase is to be detected, by performing frequency analysis on the AC component waveform of the power supply of the developing-bias applying device **40**.

The foregoing description of the exemplary embodiment of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiment was chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

1. An image forming apparatus comprising:

an image carrier configured to hold a developer image;

a developer transport unit configured to transport a developer to the image carrier by performing a rotational movement;

a voltage application unit configured to apply, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier;

a detector configured to detect a rotation phase of the developer transport unit based on an alternating-current component waveform of a power supply of the voltage application unit; and

a density correcting unit configured to correct density variations due to rotation of the developer transport unit based on the rotation phase of the developer transport unit detected by the detector,

wherein the density correcting unit does not correct the density variations when a variation amount of the alternating-current component waveform of the power supply of the voltage application unit is smaller than a predetermined value.

2. The image forming apparatus according to claim **1**,

wherein the detector is configured to divide the alternating-current component waveform into a plurality of regions corresponding to each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the developer transport unit.

3. The image forming apparatus according to claim **1**, further comprising a filter configured to remove high-frequency component noise from the alternating current component waveform of the power supply of the voltage application unit.

4. The image forming apparatus according to claim **1**, wherein the detector is configured to divide the alternating-current component waveform into a plurality of regions corresponding to frequency component in accordance with each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the developer transport unit.

5. An image forming apparatus comprising:

an image carrier configured to hold a developer image;

a developer transport unit configured to transport a developer to the image carrier by performing a rotational movement;

a voltage application unit configured to apply, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier;

a detector configured to detect a rotation phase of the developer transport unit based on an alternating-current component waveform of a power supply of the voltage application unit; and

a density correcting unit configured to correct density variations due to rotation of the developer transport unit based on the rotation phase of the developer transport unit detected by the detector, wherein the density correcting unit includes:

an acquiring unit configured to acquire density-variation information that corresponds to the rotation phase of the developer transport unit by detecting a density of an image formed by the developer transport unit,

a creating unit configured to create a correspondence table in which a correction amount corresponding to the rotation phase of the developer transport unit is specified based on the density-variation information acquired by the acquiring unit, and

an adjusting unit configured to adjust a density value of each pixel of an image to be formed based on the rotation phase of the developer transport unit detected by the detector and the correspondence table created by the creating unit.

6. The image forming apparatus according to claim **5**, further comprising a filter configured to remove high-frequency component noise from the alternating current component waveform of the power supply of the voltage application unit.

7. The image forming apparatus according to claim **5**, wherein the detector is configured to divide the alternating-current component waveform into a plurality of regions corresponding to frequency component in accordance with each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the developer transport unit.

8. An image forming apparatus comprising:

an image carrier that has a substantially cylindrical shape and is configured to hold a developer image;

a developer transport unit configured to transport a developer to the image carrier by performing a rotational movement;

a voltage application unit configured to apply, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier;

a detector configured to detect a rotation phase of the image carrier based on an alternating-current component waveform of a power supply of the voltage application unit; and

a density correcting unit configured to correct density variations due to rotation of the image carrier based on the rotation phase of the image carrier detected by the detector,

wherein the density correcting unit does not correct the density variations when a variation amount of the alternating-current component waveform of the power supply of the voltage application unit is smaller than a predetermined value.

9. The image forming apparatus according to claim **8**,

wherein the detector configured to divide the alternating-current component waveform into a plurality of regions corresponding to each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the image carrier.

10. The image forming apparatus according to claim **8**, further comprising a filter configured to remove high-frequency component noise from the alternating current component waveform of the power supply of the voltage application unit.

11. The image forming apparatus according to claim **8**, wherein the detector is configured to divide the alternating-current component waveform into a plurality of regions corresponding to frequency component in accordance with each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the developer transport unit.

12. An image forming apparatus comprising:

an image carrier that has a substantially cylindrical shape and is configured to hold a developer image;

a developer transport unit configured to transport a developer to the image carrier by performing a rotational movement;

a voltage application unit configured to apply, between the developer transport unit and the image carrier, a voltage that contains a direct-current voltage component and an alternating-current voltage component and that is used for transporting the developer from the developer transport unit to the image carrier;

a detector configured to detect a rotation phase of the image carrier based on an alternating-current component waveform of a power supply of the voltage application unit; and

a density correcting unit configured to correct density variations due to rotation of the image carrier based on the rotation phase of the image carrier detected by the detector,

wherein the density correcting unit includes

an acquiring unit configured to acquire density-variation information that corresponds to the rotation phase of the image carrier by detecting a density of an image formed by the image carrier,

a creating unit configured to create a correspondence table in which a correction amount corresponding to the rotation phase of the image carrier is specified based on the density-variation information acquired by the acquiring unit, and

an adjusting unit configured to adjust a density value of each pixel of an image to be formed based on the rotation phase of the image carrier detected by the detector and the correspondence table created by the creating unit.

13. The image forming apparatus according to claim **12**, further comprising a filter configured to remove high-frequency component noise from the alternating current component waveform of the power supply of the voltage application unit.

14. The image forming apparatus according to claim **12**, wherein the detector is configured to divide the alternating-current component waveform into a plurality of regions corresponding to frequency component in accordance with each rotation period of the developer transport unit, calculate an average value of the alternating-current component waveform, which has been divided into the plurality of regions, and detect a feature point of the calculated average value of the alternating-current component waveform so as to set a reference point of the rotation phase of the developer transport unit.

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